

E R D – R 2 4 1 2 N A C 0-001

Datasheet V1.3

24GHz Radar Module



Contents

1 Overview	- 3 -
2 Function Descriptions	- 3 -
3 Functional Characteristics	- 3 -
4 Application Scenarios	- 4 -
5 Technical Specifications	- 4 -
6 Operating Conditions	- 5 -
7 Product Dimensions and Interfaces	- 6 -
7.1 Housing Dimension	- 6 -
7.2 Pin Definitions	- 7 -
8 Installation Instructions	- 7 -
9 Warning statements	- 8 -

1 Overview

ERD-R2412NAC0-001 is a high-performance tracking radar module specifically designed for the 24GHz frequency band. This module integrates advanced microstrip antenna technology and features a one-transmit-two-receive (1T2R) configuration, ensuring stable capture of target trajectories even in complex environments. The built-in intelligent algorithm firmware enables precise recognition of human motion states and real-time multi-target tracking through high-performance digital signal processing. It is widely applied in diverse AIoT scenarios.

2 Function Descriptions

- ❖ Distance Measurement Function
It can calculate the relative distance between the human body and the sensor in real time when the human body is in motion.
- ❖ Angle Measurement Function
It can calculate the relative angle between the human body and the sensor in real time when the human body is in motion.
- ❖ Micro-movement Detection
It can detect tiny movements of the human body such as tilting the head, raising the hands, and turning around within a relatively short distance.

3 Functional Characteristics

- ❖ 24GHz ISM frequency band
- ❖ FMCW modulation
- ❖ Ripple rejection via algorithm processing
- ❖ User-definable detection range
- ❖ Trajectory tracking capability
- ❖ Distance measurement and recognition of movement direction

4 Application Scenarios

❖ Smart Home

Detects human position and trajectory, then reports the sensing data to the master control module for intelligent appliance operation.

❖ Smart Bathroom

Interval Sensing: It can identify whether the human body is approaching or moving away within the predefined distance interval, and thus achieve the function like intelligent lid opening.

5 Technical Specifications

Table 1 ERD-R2412NAC0-001 Technical Specifications

Parameters	Minimum	Typical value	Maximum	Unit	Remark
Power Supply Voltage	4.7	5.0	12.0	V	
Operating Current	2	16	140	mA	1、 This module operates with a cycle period of 50ms ; 2、 RF sleep time :32ms ; Average current: $8\pm 2\text{mA}$; 3、 RF active time: 18ms ; Average current: $30\pm 3\text{mA}$; 4、 Module complete cycle average current : $16\pm 2\text{mA}$; 5、 The peak current of this module is 140mA which Caused by RF pulse transmission with 40us.
Distance Detection Range	0.6	-	3	m	
Operating Frequency Band	24.00	-	24.25	GHz	
Output Voltage	4.7	5.0	5.3	V	

6 Operating Conditions

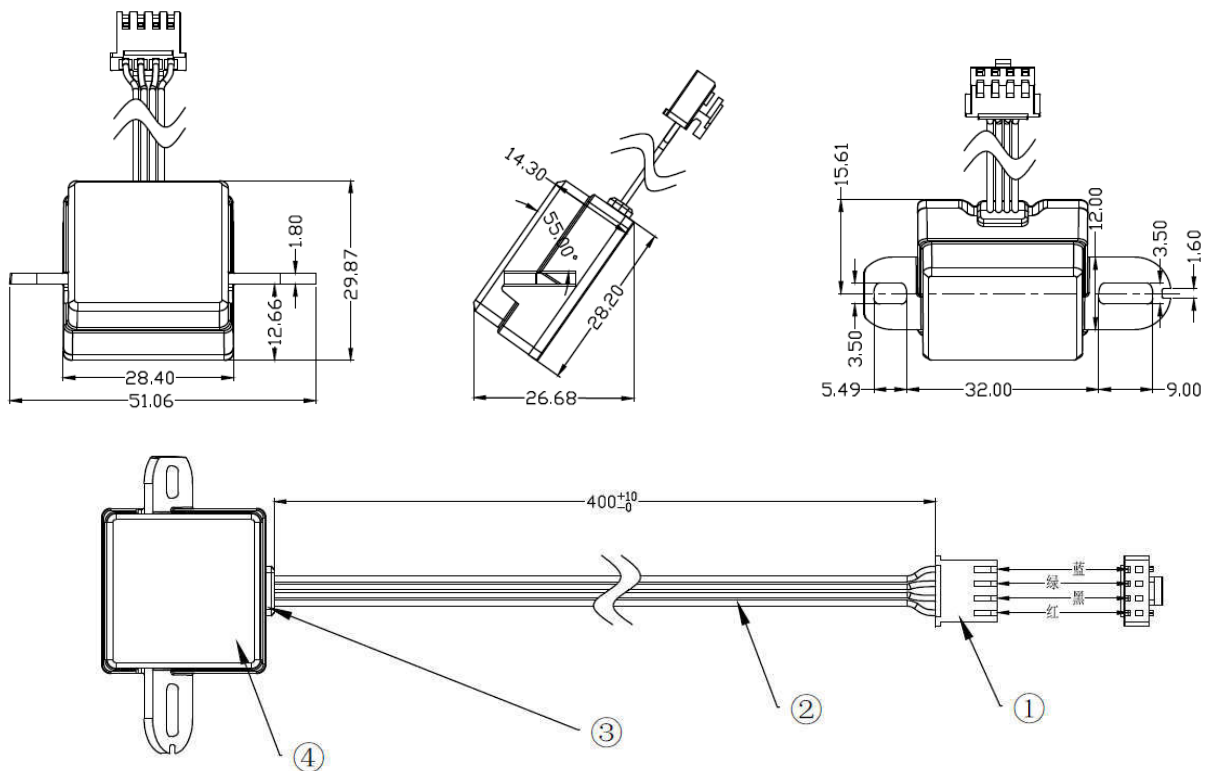
Table 2 Operating Conditions

Operating Environment Temperature	-10°C~+50°C
Storage Temperature	-20°C~+60°C
Operating Humidity	RH 25%~75%(Non-Condensing)
Storage Humidity	RH 25%~75%(Non-Condensing)
Others	The product maintains full functionality after passing the following tests: 1. 40±2°C operating temperature for 1 hour; 2. 93±3% RH for 48 continuous hours; 3. 2-hour stabilization at 25±5°C ambient temperature.

7 Product Dimensions and Interfaces

7.1 Housing Dimension

Unit: mm


Dimensional Tolerance: $\pm 0.2\text{mm}$

Unit : mm

Figure 8-1 Dimensions of the Housing of ERD-R2412NAC0-001

7.2 Pin Definitions

Table 3-1 Communication Pin Definitions

Pin Number	Pin Definition	Function Description	Remark
1-red	VCC	Power input, 4.7 - 12V, with a typical value of 5.0V.	4.7~12V
2-black	GND	Ground connection.	-
3-green	O_T1	Serial port TX pin; can be multiplexed as an output IO level.	0-5.3V
4-blue	O_T2	Serial port RX pin; can be multiplexed as an input IO level.	0-5.3V

8 Installation Instructions

❖ Confirm minimum installation gap

If the radar needs to be installed with a shell, the shell must have good wave transmission characteristics at 24GHz and must not contain metals or materials that have a shielding effect on electromagnetic waves.

❖ Installation environment requirements

The product should be used in an appropriate environment. Using it in the following conditions will affect detection performance:

- Non-human objects continuously moving within the sensing area, such as animals, continuously swinging curtains, and large green plants facing the airflow outlet..
- Large areas of strong reflection within the sensing area and strong reflectors facing the radar module antenna will cause interference.
- When installing, consider external interference factors such as air conditioning and fans on the indoor ceiling.

❖ Installation precautions

- Try to ensure the radar antenna is directly facing the area to be detected, with no obstructions around the antenna.
- Ensure the radar module's installation position is firm and stable, as movement of the radar module itself will affect detection performance.
- Ensure the back of the radar module has no moving or vibrating objects.
- If multiple 24GHz frequency radars are present, avoid direct alignment of radar beams to prevent mutual interference issues.

❖ Power supply precautions

- The power input voltage range is 5~12V, and the power ripple should be within $\pm 5\%$. Also, consider the relevant ESD and lightning surge electromagnetic compatibility design.

9 Warning statements

FCC Regulations:

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation. This device has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiated radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.



Model : ERD-R2412NAC0-001

- Consult the dealer or an experienced radio/TV technician for help.

FCC Note:

Caution: Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

RF Exposure Information

This device meets the government's requirements for exposure to radio waves.

This device is designed and manufactured not to exceed the emission limits for exposure to radio frequency (RF) energy set by the Federal Communications Commission of the U.S. Government.

This device complies with FCC radiation exposure limits set forth for an uncontrolled environment. In order to avoid the possibility of exceeding the FCC radio frequency exposure limits, human proximity to the antenna shall not be less than 20 cm (7.847 inches) during normal operation.

目 录

1. 目的 Purpose	- 11 -
2. 范围 Scope.....	- 11 -
3. 串口通信说明 Serial Communication Specification.....	- 11 -
4. 系统框图 System Block Diagram.....	- 12 -
5. 功能和协议 Functionality and Protocols.....	- 15 -
5.1 协议格式 Protocol Format.....	- 15 -
5.2 雷达开关指令 Radar Switch Commands	- 16 -
5.3 获取雷达配置 Retrieve Radar Configurations	- 18 -
5.4 修改雷达参数指令 Modify Radar Parameter Commands	- 20 -
5.5 雷达上报开关 Radar reporting switch	- 22 -
5.6 雷达主动上报感应状态 Radar Active Reporting Sensing Status	- 24 -
5.7 异常状态上报 Abnormal Situations Reporting.....	- 25 -
5.8 获取雷达固件版本号 Retrieve Radar Firmware Version Number.....	- 27 -
5.9 配置开始指令 Configure Start Commands.....	- 28 -
5.10 配置结束指令 Configure Completion Commands	- 30 -
5.11 CRC-8 算法说明 CRC-8 Algorithm Clarification.....	- 32 -

1. 目的 Purpose

本文档定义了 TOTO 智能马桶传感器的串口通讯协议。

This document defines the serial port communication protocol for the TOTO smart toilet sensor.

2. 范围 Scope

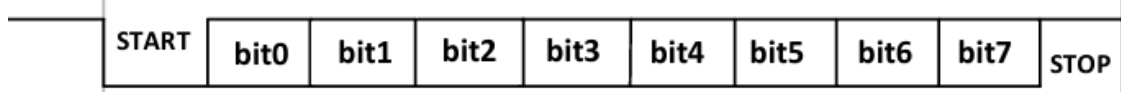
本文档适用于项目开发和维护人员。

This document is intended for use by project development and maintenance personnel.

3. 串口通信说明 Serial Communication Specification

参数名 Parameter Name	参数值 Parameter Value
波特率 Baud rate	9600
数据位 Data bit	8
奇偶校验 Parity	无 none
停止位 Stop bit	1
数据流控 Data flow control	无 none

传输格式 Frame format :

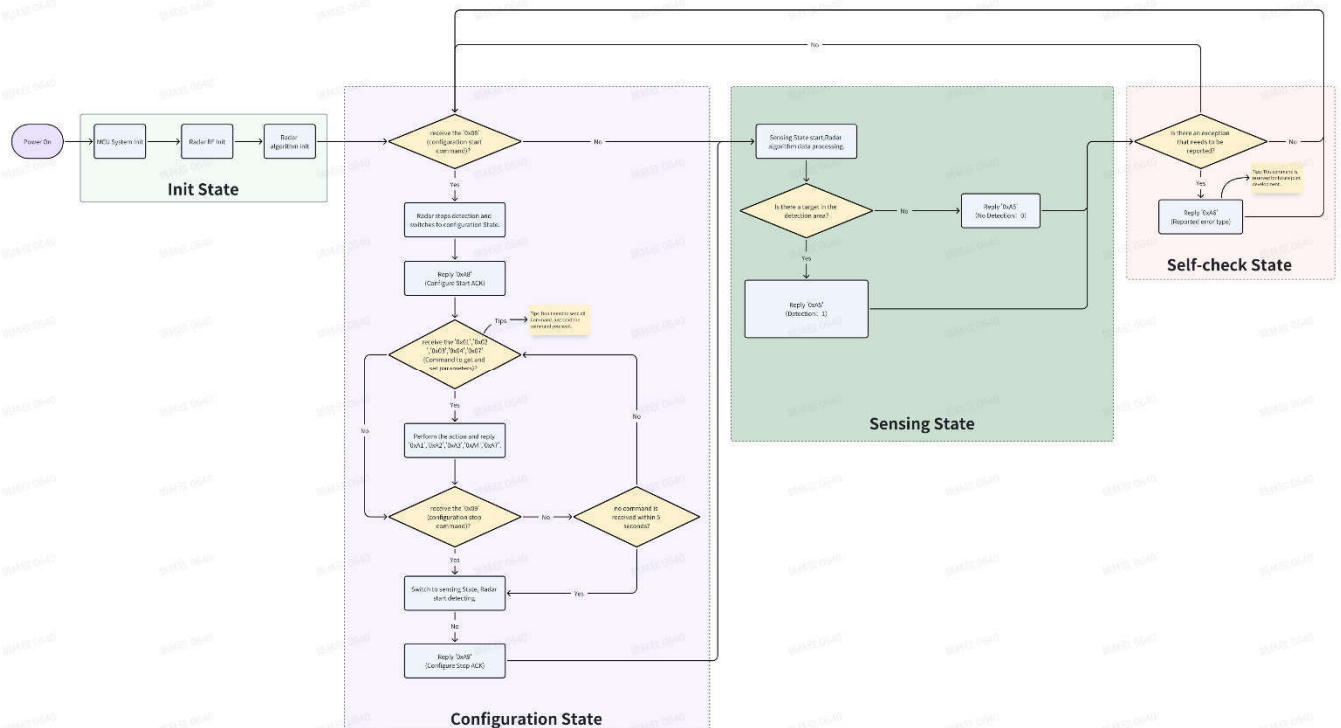


起始位为一位，用 '0' 表示。在 USART 通信中，一个数据（8 或 9 位）的发送和接收顺序可配置为从最低位到最高位（LSB），或最高位到最低位（MSB）。停止位用 '1' 表示一帧的结束，位数可配置为 1、2 位。

The start bit is one bit long, represented by '0'. In USART communication, the transmission and reception order of a data frame (8 or 9 bits) can be configured to be from the least significant bit (LSB) to the most significant bit (MSB), or from MSB to LSB. The stop bit, represented by '1', indicates the end of a frame, and the number of stop bits can be configured as 1 or 2.

误差 E (%) 为 $\leq 3\%$ 。 Error E(%) is $\leq 3\%$.

4. 系统框图 System Block Diagram



4.1 指令配置流程 Command Configuration Process

雷达指令配置流程如图 1 所示。雷达执行一条配置指令的过程包含上位机“发送指令”与雷达“回复指令 ACK”两个环节。若雷达无 ACK 回复或回复 ACK 失败，则说明雷达执行配置命令失败。

Radar command configuration process is shown in Fig.1. The process of executing a configuration command by the radar includes two steps, i.e., the upper computer 'sending the command' and the radar "replying with an ACK command". If the radar does not have an ACK reply or fails to reply ACK, it indicates that the radar has failed to execute the configuration command.

如前所述，向雷达发送任何其他命令前，开发者需先发送“配置开始指令”。指令配置完成之后，发送“配置结束指令”告知雷达配置已经结束。

As previously mentioned, before sending any other commands to the radar, developers must first send the 'configuration start command' . Once the command configuration is completed, send the 'configuration end command' to inform the radar that the configuration has ended.

例：若要读取雷达配置参数，首先上位机发送“配置开始指令”；待收到雷达 ACK 成功后，再发送“读取参数”指令；待收到雷达 ACK 成功后，最后发送“配置结束指令”指令；待雷达 ACK 成功后，表明完整的读取参数动作结束。

E.g., To read the radar configuration parameters, the Host computer first sends the 'configuration start command'. After receiving the radar ACK, it then sends the 'read parameters' command; after receiving the radar ACK, it finally sends the 'configuration end command'; after the radar ACK, it indicates that the complete action of reading parameters has ended.

超时机制：对雷达进行命令处理前，需要先发送“配置开始指令”。雷达收到“配置开始指令”之后，进入 5 秒计时的命令配置阶段。此时可以配置多条命令，且每条命令都会重启 5 秒的计时。计时阶段，雷达除指令响应外，无其他数据输出。如果 5 秒内雷达没有接收到任何命令，将自动退出接收配置指令状态，恢复正常工作模式，并输出检测数据。如需再次配置雷达，需要重新发送“配置开始指令”开启新的计时周期。

Timeout mechanism: Before issuing command processing to the radar, it is necessary to first send the 'configuration start command'. After receiving the 'configuration start command', the radar enters a 5-second command configuration phase. During this phase, multiple commands can be configured, and each command will restart the 5-second countdown. During the countdown phase, the radar will not output any data other than command responses. If the radar does not receive any commands within 5 seconds, it will automatically exit the command configuration state and return to normal operation mode, outputting detection data. To reconfigure the radar, it is necessary to send the 'configuration start command' again to initiate a new timing cycle.

建议：为了有效规避通讯阻塞现象的发生，建议向雷达发送指令的时间间隔保持在 500ms 以上。
Suggestion: To effectively avoid the occurrence of communication blocking, it is suggested that the time interval for sending commands to the radar be maintained at 500ms or more.

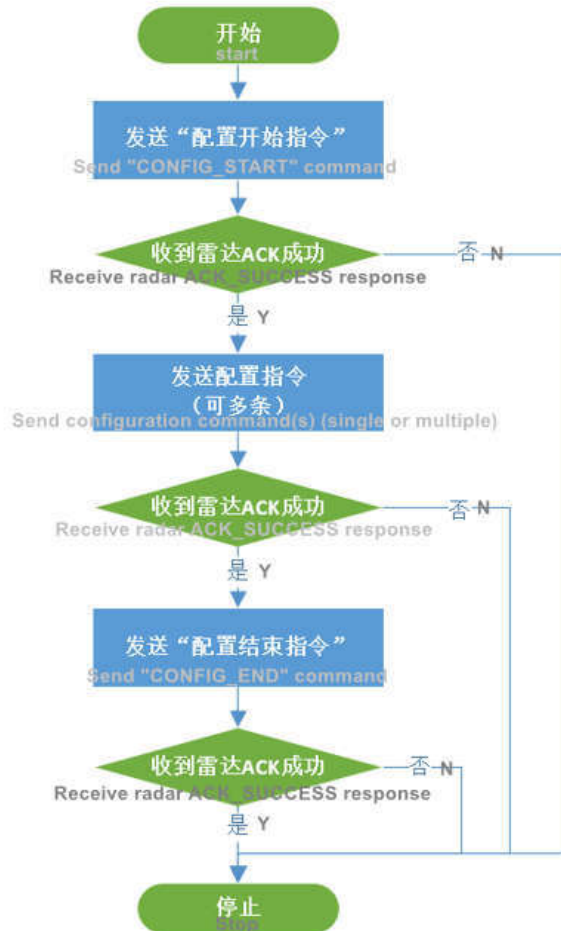


图 1 雷达指令配置流程图 // 整合到系统图中
Fig.1 Radar Command Configuration Process

4.2 感应状态 Sensing status

检测间隔以 50 毫秒为单位，最小为 50 毫秒，最大为 1000 毫秒。

The detection interval is measured in units of 50 milliseconds, with a minimum of 50 ms and a maximum of 1000 ms.

4.3 自检状态 Self-test Status

TOTO 智能马桶传感器串口通讯协议中预留 A6 指令，A6 指令的核心目的是为了加快 TOTO 适配串口协议过程中的问题定位时间，提升系统交互可靠性。

TOTO smart toilet sensor serial communication protocol reserves Command A6. The core purpose of the A6 command is to accelerate the problem localization time during the process of adapting the TOTO serial port protocol, and to enhance the reliability of system interaction.

功能和协议 Functionality and Protocols

5.1 协议格式 Protocol Format

字段 Field	长度 Length (Byte)	说明 Clarification
帧头 Frame header	1	固定为 0XD7 fixed to 0XD7
命令字 Command word	1	REQ 命令字类型 Types of REQ command word : 0x01 : 雷达开关指令 radar switch command 0x02 : 获取雷达配置 retrieve radar configurations 0x03 : 修改雷达参数 modify radar parameters 0x04 : 上报开关指令 report switch command 0x07 : 获取雷达固件版本号 retrieve radar firmware version number 0x08: 配置开始指令 configure start command 0x09: 配置结束指令 configure completion command RSP 命令字类型 Types of RSP command word : 0xA1 : 雷达开关 ACK ACK of radar switch 0xA2 : 上报雷达配置 report radar configurations 0xA3 : 修改参数 ACK ACK of modifying parameter 0xA4 : 雷达上报开关 ACK ACK of radar reporting switch 0xA5 : 雷达主动上报 radar active reporting 0xA6 : 异常情况上报 report abnormal situations 0xA7 : 上报雷达固件版本号 report radar firmware version number 0xA8: 配置开始 ACK ACK of configuration start 0xA9: 配置结束 ACK ACK of configuration completion
数据长度 Data Length	1	单指数据字段的长度，不包含其他字段。 Referring to the length of a single data field, not including other fields.
数据 Data	n	有效数据 valid data
校验和 Checksum	1	CRC-8 校验，从命令字字段到最后一个数据字段计算 CRC-8 checksum calculation, from the command word field to the last data field
帧尾 Frame Tail	1	固定为 0xF8 fixed to 0xF8

5.2 雷达开关指令 Radar Switch Commands

如需打开雷达，下位机可下发如下指令。雷达开关状态默认为开启。后续可以通过接收该指令来关闭与再次开启雷达。详细数据格式如下：

To activate the radar, the lower computer can issue the following commands. The default state of the radar switch is set to ON. It can subsequently be turned OFF and back ON by receiving this command. The detailed data format is as follows:

上位机发送 Host computer sends :

字段 Field	长度 Length (Byte)	说明 Clarification
帧头 Frame header	1	固定为 0XD7 fixed to 0XD7
命令字 Command word	1	0x01: 雷达开关 radar switch
数据长度 Data Length	1	0x01
数据 Data	1	字节 1 byte 1 : 指令类型 command types 0x00 : 关闭雷达 deactivate radar 0x01 : 开启雷达 activate radar
校验和 Checksum	1	CRC-8 校验, 从命令字字段到最后一个数据字段计算 CRC-8 checksum calculation, from the command word field to the last data field
帧尾 Frame Tail	1	固定为 0xF8 fixed to 0xF8

示例 e.g. : D7 01 01 01 crc8 F8

雷达 MCU 返回 Radar MCU returns :

字段 Field	长度 Length (Byte)	说明 Clarification
帧头 Frame header	1	固定为 0xD7 fixed to 0xD7
命令字 Command word	1	0xA1: 雷达开关 ACK ACK of radar switch
数据长度 Data Length	1	0x02
数据 Data	2	字节 1 byte 1 : 雷达开关状态 radar switch status 0x00 : 雷达关闭 radar off 0x01 : 雷达开启 radar on 字节 2 byte 2 : 设置结果 configuration result 0x00 : 设置失败 configuration failed 0x01 : 设置成功 configuration successful
校验和 Checksum	1	CRC-8 校验, 从命令字段到最后一个数据字段计算 CRC-8 checksum calculation, from the command word field to the last data field
帧尾 Frame Tail	1	固定为 0xF8 fixed to 0xF8

示例 e.g. : D7 A 02 00 01 crc8 F8

5.3 获取雷达配置 Retrieve Radar Configurations

如需获取雷达配置，上位机下发如下指令即可。其中，探测灵敏度默认为档位 3，雷达开关状态默认为雷达开启，雷达上报开关状态也默认为开启。雷达接收指令后将实时返回雷达参数修改成功与否。详细格式请查阅下表。

To obtain radar configurations, the Host computer may issue the following commands. By default, the detection sensitivity is set to level 3, the radar switch status defaults to ON, and radar reporting switch is also set to ON by default. The radar will return real-time feedback indication whether parameter modification was successful. Refer to the table below for detailed format specifications.

上位机发送 Host computer sends :

字段 Field	长度 Length (Byte)	说明 Clarification
帧头 Frame header	1	固定为 0XD7
命令字 Command word	1	0x02: 获取雷达配置 retrieve radar configurations
数据长度 Data length	1	0x00
数据 Data	0	无数据 no data
校验和 Checksum	1	CRC-8 校验，从命令字字段到最后一个数据字段计算 CRC-8 checksum calculation, from the command word field to the last data field
帧尾 Frame tail	1	固定为 0xF8 fixed to 0xF8

示例 e.g. : D7 02 00 CRC8 F8

雷达 MCU 返回 Radar MUC returns :

字段 Field	长度 Length (Byte)	说明 Clarification
帧头 Frame header	1	固定为 0xD7 fixed to 0xD7
命令字 Command word	1	0xA2 : 上报雷达配置 report radar configuration
数据长度 Data length	1	0x03
数据 Data	3	字节 1 : 探测灵敏度 (从低到高五个档位依次对应 0x00~0x04) byte 1: Detection sensitivity(From low to high, the five levels correspond to 0x00~0x04 respectively.) 0x00 档位 1, 探测范围为 0.8m(level 1, detection range:0.8m) 0x01 档位 2, 探测范围为 1.1m(level 2, detection range:1.1m) 0x02 档位 3, 探测范围为 1.4m(level 3, detection range:1.4m) 0x03 档位 4, 探测范围为 1.7m(level 4, detection range:1.7m) 0x04 档位 5, 探测范围为 2.0m(level 5, detection range:2.0m) 字节 2 : 雷达开关状态 byte 2: radar switch status 0x00 : 雷达关闭 radar off 0x01 : 雷达开启 radar on 字节 3 : 雷达上报开关状态 byte 3: radar reporting switch status 0x00 : 主动上报关闭 radar report on 0x01 : 主动上报开启 radar report off
校验和	1	CRC-8 校验, 从命令字字段到最后一个数据字段计算 CRC-8 checksum calculation, from the command word field to the last data field
帧尾	1	固定为 0xF8 fixed to 0xF8

示例 e.g. : D7 A2 03 00 01 01 CRC F8

5.4 修改雷达参数指令 Modify Radar Parameter Commands

如需修改雷达参数，上位机下发如下指令即可。其中，探测灵敏度默认为档位 3。雷达接收指令后将实时且持续返回修改结果。详细格式请查阅下表。

To modify radar parameters, the Host computer may issue the following commands. By default, the detection sensitivity is set to level 3. After receiving the radar commands, radar will continuously return the modified results in real-time.

上位机发送 Host computer sends :

字段 Field	长度 Length (Byte)	说明 Clarification
帧头 Frame header	1	固定为 0xD7 Fixed to 0xD7
命令字 Command word	1	0x03 : 修改雷达参数 modify radar parameter
数据长度 Data length	1	0x01
数据 Data	1	字节 1 : 探测范围 (从低到高五个档位依次对应 0x00~0x04) byte 1: Detection sensitivity(From low to high, the five levels correspond to 0x00~0x04 respectively.) 0x00 档位 1, 探测范围为 0.8m(level 1, detection range:0.8m) 0x01 档位 2, 探测范围为 1.1m(level 2, detection range:1.1m) 0x02 档位 3, 探测范围为 1.4m(level 3, detection range:1.4m) 0x03 档位 4, 探测范围为 1.7m(level 4, detection range:1.7m) 0x04 档位 5, 探测范围为 2.0m(level 5, detection range:2.0m)
校验和 Checksum	1	CRC-8 校验, 从命令字字段到最后一个数据字段计算 CRC-8 checksum calculation, from the command word field to the last data field
帧尾 Frame tail	1	固定为 0xF8 fixed to 0xF8

示例 e.g. : D7 03 01 00 CRC F8

雷达 MCU 返回 Radar MCU returns :

字段 Field	长度 Length (Byte)	说明 Clarification
帧头 Frame header	1	固定为 0xD7 fixed to 0xD7
命令字 Command word	1	0xA3 : 修改参数 ACK ACK of modifying parameters
数据长度 Data length	1	0x02
数据 Data	2	字节 1 : 探测范围 (从低到高五个档位依次对应 0x00~0x04) byte 1: Detection sensitivity(From low to high, the five levels correspond to 0x00~0x04 respectively.) 0x00 档位 1, 探测范围为 0.8m(level 1, detection range:0.8m) 0x01 档位 2, 探测范围为 1.1m(level 2, detection range:1.1m) 0x02 档位 3, 探测范围为 1.4m(level 3, detection range:1.4m) 0x03 档位 4, 探测范围为 1.7m(level 4, detection range:1.7m) 0x04 : 档位 5, 探测范围为 2.0m(level 5, detection range:2.0m) 字节 2 : 设置结果 byte 2: configuration result 0x00 : 设置失败 configuration failed 0x01 : 设置成功 configuration successful
校验和 Checksum	1	CRC-8 校验, 从命令字字段到最后一个数据字段计算 CRC-8 checksum calculation, from the command word field to the last data field
帧尾 Frame tail	1	固定为 0xF8 fixed to 0xF8

示例 e.g. : D7 A3 02 00 01 CRC F8

5.5 雷达上报开关 Radar reporting switch

如需开关雷达主动上报，上位机下发如下指令即可。其中，雷达上报开关状态默认为开启。雷达接收指令后将实时返回雷达主动上报开关设置成功与否。详细格式请查阅下表。

To configure radar active reporting switch, the Host computer may sends the following commands. By default, radar reporting switch is set to ON. After receiving the radar commands, radar will return continuously and in real-time whether the radar active reporting switch setting is successful or not.

上位机发送 Host computer sends :

字段 Field	长度 Length (Byte)	说明 Clarification
帧头 Frame header	1	固定为 0xD7 fixed to 0xD7
命令字 Command word	1	0x04 : 上报开关指令 report switch command
数据长度 Data length	1	0x01
数据 Data	1	字节 1 : byte 1 0x00 : 关闭主动上报 deactivate active reporting 0x01 : 打开主动上报 activate active reporting
校验和 Checksum	1	CRC-8 校验, 从命令字字段到最后一个数据字段计算 CRC-8 checksum calculation, from the command word field to the last data field
帧尾 Frame tail	1	固定为 0xF8 fixed to 0xF8

使能射频开关的示例 Example of enabling the RF switch : D7 04 01 01 CRC F8

雷达 MCU 返回 Radar MCU returns :

字段 Field	长度 Length (Byte)	说明 Clarification
帧头 Frame header	1	固定为 0XD7
命令字 Command word	1	0xA4 : 雷达上报开关 ACK
数据长度 Data length	1	0x02
数据 Data	2	字节 1 : 主动上报开关状态 byte 1: active report switch status 0x00 : 主动上报关闭 active reporting OFF 0x01 : 主动上报开启 active reporting ON 字节 2 : 设置结果 byte 2: configuration result 0x00 : 设置失败 configuration failed 0x01 : 设置成功 configuration successful
校验和	1	CRC-8 校验, 从命令字字段到最后一个数据字段计算 CRC-8 checksum calculation, from the command word field to the last data field
帧尾	1	固定为 0xF8 fixed to 0xF8

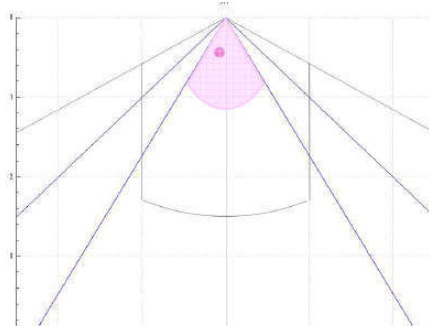
接收示例 receiving example : D7 A4 02 01 CRC F8

5.6 雷达主动上报感应状态 Radar Active Reporting Sensing Status

在以下范围内发送检测 (0x01)，在该范围外发送未检测 (0x00)。

Data 0x01 will be reported if human is detected within the pink region. Data 0x00 will be reported if human is detected outside the pink region.

检测区域 detection range : $\leq 1500(1200)\text{mm}(\pm 31\text{deg})$



详细格式如下 Detailed format is as follows :

字段 Field	长度 Length (Byte)	说明 Clarification
帧头 Frame header	1	固定为 0xD7 fixed to 0xD7
命令字 Command word	1	0xA5 : 雷达主动上报 radar active reporting
数据长度 Data length	1	0x01
数据 Data	1	0x01 : 检测到人体 Human body is detected. 0x00 : 未检测到人体 no human body detected
校验和 Checksum	1	CRC-8 校验, 从命令字字段到最后一个数据字段计算 CRC-8 checksum calculation, from the command word field to the last data field
帧尾 Frame tail	1	固定为 0xF8 fixed to 0xF8

示例 e.g. : D7 A5 01 01 CRC F8

5.7 异常状态上报 Abnormal Situations Reporting

雷达 MCU 发送 Radar MCU sends :

字段 Field	长度 Length (Byte)	说明 Clarification
帧头 Frame header	1	固定为 0xD7 fixed to 0xD7
命令字 Command word	1	0xA6: 雷达异常上报 radar abnormal situations reporting
数据长度 Data length	1	0x01
数据 Data	1	字节 1 : 错误类型 byte 1: error type 0xF1 : 雷达通信繁忙 busy radar communication 0xF2 : 接收到的数据异常 abnormal received data 0xF3 : 视后续情况而定 reserved
校验和 Checksum	1	CRC-8 校验, 从命令字字段到最后一个数据字段计算 CRC-8 checksum calculation, from the command word field to the last data field
帧尾 Frame tail	1	固定为 0xF8 fixed to 0xF8

示例 e.g. : D7 A6 01 F1 CRC F8

● A6 指令参数清单 A6 command parameter list

A6 仅会上报如下异常状态, 异常状态对应的解释可参见注释。The A6 command only reports the following abnormal statuses. Refer to the comments for explanations of each error statuses.

```
#define ERR_WRONG_PARAM      0      /**< Params Error */
#define ERR_SYSTEM_BUSY      1      /**< System Busy, Send message later */
#define ERR_CHECK_FAILED      2      /**< Frame check failed */
#define ERR_WRONG_STATE      3      /**< Wrong State, Send message later */
#define ERR_UNSUPPORT_CMD    4      /**< Unsupport cmd type */
```

- 指令中参数格式不正确或参数不符合要求区间时, 将上报 ERR_WRONG_PARAM(0)。If parameter format in the command is incorrect, or the parameter values are out of valid range, ERR_WRONG_PARAM(0) would be reported.

当下发的参数格式不正确, 如参数长度过长。或者下发的参数不符合要求区间, 如 0x03 指令中的档位值设置为 0x05。雷达将上报 ERR_WRONG_PARAM(0), 此时上层需要检查参数设定是否正确, 修复错误后重新下发指令。If the issued parameter format is incorrect (e.g., the parameter length exceeds limit) or the parameters are out of the valid range (e.g., level value is set to 0x05 in 0x03 command), the radar would report ERR_WRONG_PARAM(0). In this case, upper-layer must verify parameter setting, correct the errors, and resend the command.

- 系统指令接收缓存区已满时，收到新的指令。将上报 ERR_SYSTEM_BUSY(1)。 If a new command is received while the system command reception buffer is full, ERR_SYSTEM_BUSY(1) would be reported.

当系统的接收缓存区已满时，再收到新的指令将会导致丢包。此时收到新的指令后，雷达将上报 ERR_SYSTEM_BUSY(1)，上层等待之前下发的指令回复执行状态后，再发新的指令。 If the system command reception buffer is full, receiving new commands will cause packet loss. In this case, after receiving a new command, the radar will report ERR_SYSTEM_BUSY(1). The upper-layer must wait for the execution status response of the previously issued command before sending new commands.

- 数据帧的头、尾、CRC、数据长度校验失败时，将上报 ERR_CHECK_FAILED(2)。 If the verification of the frame header, frame tail, CRC, or data length fails, ERR_CHECK_FAILED(2) would be reported.

当数据帧的校验信息(帧头、帧尾、CRC、数据长度)中的任意一个出现校验失败时，系统将上报 ERR_CHECK_FAILED(2)，此时需要上层检查校验信息是否正确，如果校验信息下发正确则有可能是通讯线路不可靠导致的丢包，可尝试复发指令或优化通信电路设计。 If any check of the data frame's verification fields(header, tail, CRC, or data length) fails, the system would report ERR_CHECK_FAILED(2). In this case, the upper-layer system must verify the correctness of the sent verification data. If the verification data is confirmed correct, the issue may stem from unreliable communication(e.g., packet loss). Recommended actions include re-transmitting the command or optimize the communication circuit design.

- 雷达初始化时，接收到串口指令将上报 ERR_WRONG_STATE(3)。 During the stage of radar initialization, ERR_WRONG_STATE(3) would be reported if the system receives any serial port commands.

系统上电后，雷达需要 10S 内的初始化时间。在初始化阶段雷达算法需要进行连续计算，在该状态下雷达将不会处理串口指令。如果接收到指令，系统将回复 ERR_WRONG_STATE(3)，请等待初始化结束后再发送该指令。 After the system is powered on, the radar requires an initialization time of within 10 seconds. During the initialization phase, the radar algorithm requires continuous computation, during which the radar will not process serial port commands. If a command is received, the system will reply with ERR_WRONG_STATE(3). Please wait until the initialization is completed before re-sending the command.

- 当系统下发的指令非协议内的指令时，将上报 ERR_UNSupport_CMD(4)。 If the system issues unsupported command type, ERR_UNSupport_CMD(4) would be reported.

5.8 获取雷达固件版本号 Retrieve Radar Firmware Version Number

如需获取当前雷达固件版本号，可通过该指令查询，雷达接收指令后将返回当前雷达 MCU 固件版本号。详细格式请查阅下表。

To retrieve current radar firmware version number, The query can be performed through this commands. After receiving the command, system will return current radar MCU firmware version number. Refer to the table below for detailed format.

上位机发送 Host computer sends :

字段 Filed	长度 Length (Byte)	说明 Clarification
帧头 Frame header	1	固定为 0xD7 fixed to 0xD7
命令字 Command word	1	0x07: 获取雷达 MCU 固件版本号 retrieve radar MCU firmware version number
数据长度 Data length	1	0x00
数据 Date	0	无
校验和 Checksum	1	CRC-8 校验，从命令字字段到最后一个数据字段计算 CRC-8 checksum calculation, from the command word field to the last data field
帧尾 Frame tail	2	固定为 0xF8 fixed to 0xF8

示例 e.g. : D7 07 00 CRC F8

雷达 MCU 返回 Radar MCU returns :

字段 Field	长度 Length (Byte)	说明 Clarification
帧头 Frame header	1	固定为 0xD7
命令字 Command word	1	0xA7: 上报雷达 MCU 固件版本号
数据长度 Data length	1	0x03
数据 Data	3	字节 1 : 大版本号 byte 1: large version number 字节 2 : 中版本号 byte 2: medium version number 字节 3 : 小版本号 byte 3: small version number
校验和 Checksum	1	CRC-8 校验，从命令字字段到最后一个数据字段计算 CRC-8 checksum calculation, from the command word field to the last data field
帧尾 Frame tail	1	固定为 0xF8 fixed to 0xF8

接收示例 receiving example : D7 A7 03 01 00 00 CRC F8

5.9 配置开始指令 Configure Start Commands

对雷达下发的任何其他命令必须在此命令下发后方可执行。

Any other commands issued to the radar must be executed only after this command has been issued.

上位机发送 Host computer sends :

字段 Field	长度 Length (Byte)	说明 Clarification
帧头 Frame header	1	固定为 0xD7 fixed to 0xD7
命令字 Command word	1	0x08: 雷达进入“接收配置指令状态” Radar enters 'configuration command reception status'
数据长度 Data length	1	0x00
数据 Data	0	无 none
校验和 Checksum	1	CRC-8 校验, 从命令字字段到最后一个数据字段计算 CRC-8 checksum calculation, from the command word field to the last data field
帧尾 Frame tail	2	固定为 0xF8 fixed to 0xF8

示例 e.g. : D7 08 00 CRC F8

雷达 MCU 返回 Radar MCU returns :

字段 Field	长度 Length (Byte)	说明 Clarification
帧头 Frame header	1	固定为 0xD7 fixed to 0xD7
命令字 Command word	1	0xA8: 上报雷达是否成功进入“接收配置指令状态” report if radar has successfully entered ‘configuration command reception status’ .
数据长度 Data length	1	0x01
数据 Data	1	字节 1 : 指令执行情况 byte 1: command execution situations 0x00 : 执行失败, 未进入“接收配置指令状态” execution failed, not enter ‘configuration command reception status’ 0x01 : 执行成功, 进入“接收配置指令状态” execution successful, enter ‘configuration command reception status’
校验和 Checksum	1	CRC-8 校验, 从命令字字段到最后一个数据字段计算 CRC-8 checksum calculation, from the command word field to the last data field
帧尾 Frame tail	1	固定为 0xF8 fixed to 0xF8

接收示例 receiving example : D7 A8 01 01 CRC F8

5.10 配置结束指令 Configure Completion Commands

对雷达下发的任何其他命令必须在此命令下发后方可执行。

Any other commands issued to the radar must be executed only after this command has been issued.

上位机发送 Host computer sends :

字段 Filed	长度 Length (Byte)	说明 Clarification
帧头 Frame header	1	固定为 0xD7 fixed to 0xD7
命令字 Command word	1	0x09: 雷达退出 “接收配置指令状态” Radar exits the ‘receiving configuration command status’ .
数据长度 Data length	1	0x00
数据 Date	0	无
校验和 Checksum	1	CRC-8 校验, 从命令字字段到最后一个数据字段计算 CRC-8 checksum calculation, from the command word field to the last data field
帧尾 Frame tail	2	固定为 0xF8 fixed to 0xF8

示例 e.g. : D7 09 00 CRC F8

雷达 MCU 返回 Radar MCU returns :

字段 Field	长度 Length (Byte)	说明 Clarification
帧头 Frame head	1	固定为 0xD7 fixed to 0xD7
命令字 Command word	1	0xA9: 上报雷达是否成功退出 “接收配置指令状态” Report if radar has successfully exited ‘receiving configuration command status’ .
数据长度 Data Length	1	0x01
数据 Data	1	字节 1 : 指令执行情况 byte 1:command execution status 0x00 : 执行失败, 未退出 “接收配置指令状态” execution failed, not exit ‘receiving configuration command status’ 0x01 : 执行成功, 退出 “接收配置指令状态” execution successful, exit receiving configuration command status’
校验和 Checksum	1	CRC-8 校验, 从命令字字段到最后一个数据字段计算 CRC-8 checksum calculation, from the command word field to the last data field
帧尾 Frame tail	1	固定为 0xF8 fixed to 0xF8

接收示例 receiving example : D7 A9 01 01 CRC F8

5.11 CRC-8 算法说明 CRC-8 Algorithm Clarification

CRC-8 算法函数如下 CRC-8 algorithm is given as follows :

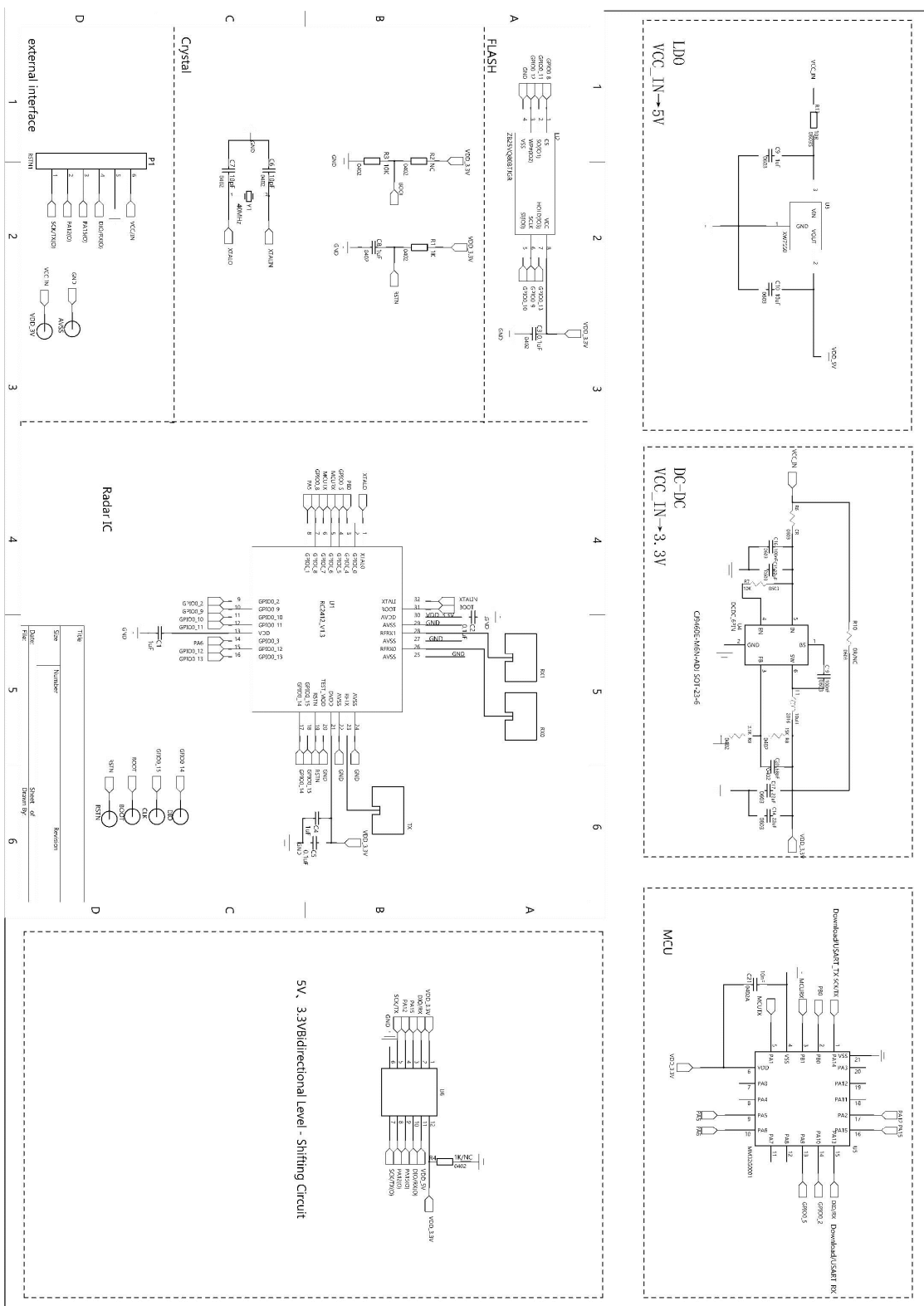
```
/**
 * @brief Get crc-8(0x1D, 0x95) check code
 * @note
 * @param *data: check data
 * @param length: data length
 * @retval
 */
uint8_t crc8(uint8_t *data, uint8_t length)
{
    uint8_t crc = 0;
    uint8_t i = 0;
    uint8_t j = 0;

    for(i = 0; i < length; i++)
    {
        crc ^= data[i];

        for(j = 0; j < 8; j++)
        {
            if(crc & 0x80)
            {
                crc = (crc << 1) ^ 0x1D;
            }
            else
            {
                crc <<= 1;
            }
        }
    }

    return crc;
}
```

模块电路图



Appendix 3

产品性能标准及检测方法

1) 频偏测试

项目编号	RD102024010	产品名称	ERD-R2412NAC0-001 马桶传感器
测试地点	研发实验室	测试时间	2025-3-27
测试设备与工具	频谱仪、24G 接收天线、射频线、DC 5V 供电。		
测试方法	将模块天线面贴近 24G 接收天线 10cm 左右，等待频谱仪扫频完成，查看峰值所在频段。		
判断标准	模块发射信号在 24.00-24.25GHZ 频段内，扫频带宽为 250M。		
测试场景示意图			
			
样品编号	测试结果		
#1	PASS		
#2	PASS		
#3	PASS		
#4	PASS		
#5	PASS		
测试结论：PASS			

2) 电气性能测试

项目编号	RD102024010	产品名称	ERD-R2412NAC0-001 马桶传感器
测试地点	研发实验室	测试时间	2025-3-27
测试设备与工具	线性直流电源、串口工具、PC。		
测试方法	1. 调节电源供电电压为 4.7V/8V/12V，依次测试三个电压下传感器感应功能； 2. 调节电源供电电压为 4.7V/8V/12V，依次测试三个电压下 TX、RX 通讯电压。		
判断标准	1. 各电压下传感器成功触发人检信号及无人信号； 2. 各电压下传感器下 TX、RX 通讯电压为 5V±0.3V。		
样品编号	感应功能测试结果	通讯电压测试结果	
#1	PASS	PASS	
#2	PASS	PASS	
#3	PASS	PASS	
#4	PASS	PASS	
#5	PASS	PASS	
测试结论：PASS			

3) 功耗测试

项目编号	RD102024010	产品名称	ERD-R2412NAC0-001 马桶传感器
测试地点	研发实验室	测试时间	2025-3-27
测试设备与工具	线性直流电源、Esight 电流仪、PC、串口工具。		
测试方法	调节电源供电电压 5V，使用 esight 观察电流仪软件界面 2min，记录平均电流。		
判断标准	平均电流：16±2mA。		
样品编号	测试结果		
#1	PASS		
#2	PASS		
#3	PASS		
#4	PASS		
#5	PASS		
测试结论：PASS			

4) 移动感应范围测试

项目编号	RD102024010	产品名称	ERD-R2412NAC0-001 马桶传感器
测试地点	研发实验室	测试时间	2025-3-27
测试设备与工具	PC、串口工具、卷尺。		
测试方法	1. 传感器距离地面 75cm，与水平线夹角 90° 摆放； 2. 测试人员从感应范围外（距传感器 3m）以 0.5m/s 靠近至传感器 0.98m 处，观察上位机是否出现人检信号； 3. 重复测 3 次，更换方向，直至 -30° / 0° / 30° 三个方向完成测试。		
判断标准	3 个方向 3 次测试均出现人检信号。		

测试角度示意图



样品编号	测试结果
#1	PASS
#2	PASS
#3	PASS
#4	PASS
#5	PASS
测试结论 : PASS	

Appendix 4

雷达模块系列成品检验标准

		技术指导文件			
文件编号：EDK-Q3-PGB-005 文件名称：雷达模块系列成品检验标准 版本/版次：A/0 受 控 章：					
制(修)订		审 核		批 准	
制订日期		制订部门		生效日期	
2024-03-26		品管部		2024-03-26	
会 签		/			

EARDATEK

1. 目的

建立雷达模块系列成品检验标准进行质量控制。

2. 范围

本检验标准适用于公司品管部对雷达模块系列成品检验。

3. 缺陷等级定义

3.1 致命缺陷 (Cr)

指功能测试影响正常使用的缺陷, 功能测试参数不符合产品要求的缺陷, 影响产品主要功能测试指标和功能测试的缺陷, 危害或危及使用者人身安全的缺陷, 用 Cr 表示。

3.2 主要缺陷 (Ma)

指影响产品使用和功能测试的缺陷, 产品装配产生的缺陷, 严重影响产品外观的缺陷, 用 Ma 表示 ;

3.3 次要缺陷 (Mi)

指轻微影响产品外观的缺陷, 用 Mi 表示。

注 : 下表结构检验标准中各项检测项目的缺陷等级均按其程度在所对应行后面的方框中打 “√” 来标识其类别。

4. 职责与权限

4.1 品管部

- a . 负责本标准的编制、修订、审核、批准、发布 ;
- b . 负责样品的签核、发放 ;
- c . 负责检验、不良判定及最终裁决。

5. 抽样标准

外观检测按送检数量的 5% 进行抽样, 除外观外的测试项目抽检 5pcs, Cr : Ac=0 Re=1 ; Ma: Ac=0 Re=1 ; Mi: Ac= 1 Re=2。

6. 作业内容

产品名称	检验项目	检验工具	检验标准	记录表单
雷达模块	外观	1. 手套 2. 静电手环	1.检查成品实物的型号、数量、生产批次与标签内容、《成品报检单》是否一致。 2.检查成品机外观，确认无元器件破损、切割偏移和虚焊漏焊，板边无毛刺。 3.二维码无缺损、划伤、模糊，外壳无明显色差/色点、划伤、脏污、溢胶残留等不良影响。 4.检查排线无破皮、压痕，排线端子线序正确，端子无松动，半插、破损、变形，端子卡扣弹性正常，长度、颜色符合规格书标准要求。 5.检查编带、托盘、包装袋无破损，产品方向一致。 6.包装要求无变形。 7.RoHS 标签要求不漏贴。	
	功能测试	1. 手指套 2. 样机 3. 测试架	选用与产品型号相对应的测试工装，用样机校对，分别测试输入电压、功耗、移动感应距离、频偏、延时时间、测试点电压，测试值等符合《产品性能指标要求》，判定合格。	

Appendix 5

成品检验指导书

EARDATEK										广州易而达科技股份有限公司											
成品检验作业指导书																					
产品名称				感应雷达				文件编号		EDK-Q3-PGB-030		制定单位		品管部		编制		审 核		批准	
产品型号				24G雷达模组				作业项目		成品检验		版本		A0							
								制定日期		2024/5/12		页次		1/1							
设备及工具：																					
1. 测试软件																					
2. 配备测试软件的电脑																					
作业规格：																					
1. 检查产品包装及外观、功能；检验依据GB/T2828.1-2012 II级进行随机抽样，外观检验MA=0.65 MI=1.5，功能检验，Ac=0 Re=1，包含测距精度测试，移动感应范围测试																					
2. 确认报检单上的品号、规格与产品标签或清单上要求一致；外观检验，内部不可出现异响，外观不可出现脏污、扣位不良、溢胶、断线、明显断差、批锋、缝隙、碰伤、刮花，线材卡位松动松动，包装整洁，不可出现破损；参考规格书，使用卡尺测量尺寸值，如图1；																					
3. 测距精度测试，标准反射面在预设位置1m±2cm内往返运动测试产品值在±5cm内为合格，如图2																					
4. 移动感应范围测试：以产品前端为中心，用卷尺在地面45°/0°/-45°标记距离刻度线，分别测试每个档位的感应距离符合规格书要求，如图3																					
5. 确认产品报检数量、报检规格型号、包装方式、标签是否与规格一致，如图4																					
6. 检验合格后填写报表记录，产品合格进仓																					
作业程序：																					
1. 外观检验																					
2. 功能测试																					
作业注意事项：																					
1. 戴好防静电手环																					
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